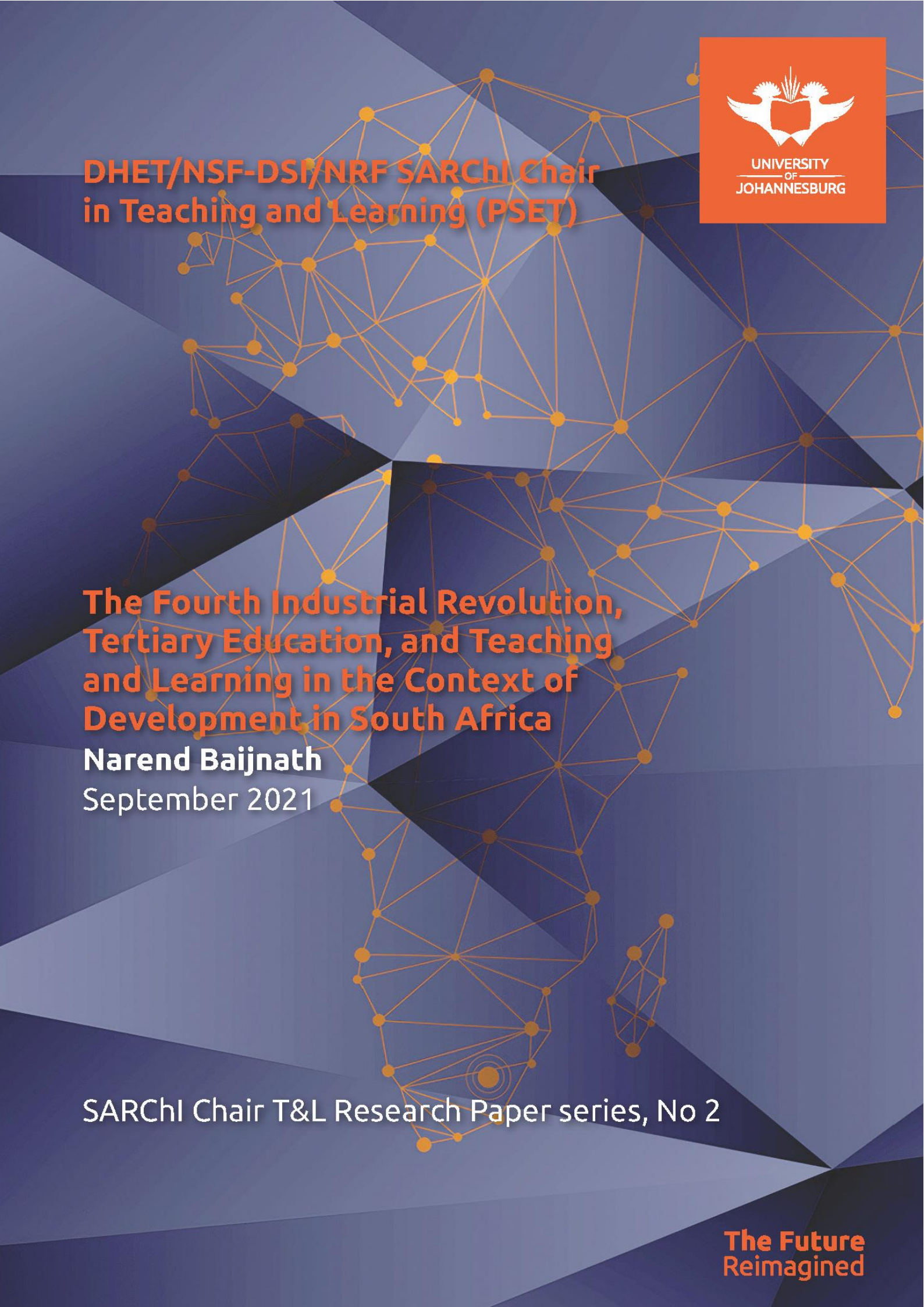

DHET/NSF-DSI/NRF SARChI Chair in Teaching and Learning (PSET)

UNIVERSITY OF JOHANNESBURG

The Fourth Industrial Revolution, Tertiary Education, and Teaching and Learning in the Context of Development in South Africa

Narend Baijnath

September 2021

SARChI Chair T&L Research Paper series, No 2

The Future Reimagined

Contents

1. Introduction 3

2. What is the Fourth Industrial Revolution? 3

3. Benefits and Promise of the 4IR in Advancing Development 5

4. Contested Possibilities of the 4IR 8

5. The Potential for Tertiary Education, Teaching and Learning 10

6. Implications for Curriculum 15

7. Enabling Conditions 18

8. Imperatives for Change flowing from the 4IR. 20

9. A Supportive Infrastructure, Access to Devices, and Cost-Effective Connectivity 23

10. Conclusion 25

Abbreviations and acronyms 26

References 27

1. Introduction

In recent years, the emerging phenomenon of a Fourth Industrial Revolution (4IR) has gained recognition in developing and developed countries alike. Many have sensed its inevitability and therefore the imperative to ensure informed and proactive responses at state, sectoral and institutional levels. In South Africa, such responses to the 4IR have gathered considerable momentum with one initiative driven by the Presidency and another by a Ministerial Task Team (MTT) on the 4IR established by the Minister of Higher Education and Training. Mindful of the many initiatives and opinions on the 4IR, the promise it holds for development nationally, for the higher education sector, and the responses it has impelled, this literature review aspires to assist our understanding of this phenomenon. Furthermore, it explores the promise the 4IR holds for promoting national development and the value it may hold for tertiary education, teaching, and learning. It reflects upon what interventions may be necessary to leverage its potential while seeking to understand wider implications regarding policy, planning, and development at the institutional and national levels. Finally, the challenges and obstacles that may need to be overcome are identified.

2. What is the Fourth Industrial Revolution?

Klaus Schwab (2015) has been the leading and arguably most influential proponent of the idea of a technological revolution termed the "Fourth Industrial Revolution", elsewhere also referred to as Industry 4.0 (Marwala, 2020 (a): 25). However, there is not necessarily complete agreement. Industry 4.0 has been argued to be a part of the 4IR with its roots in Germany's manufacturing industry in the early 2000s (Gleason, 2018: 2), suggesting that developments recognisably associated with what is called the 4IR did not occur in a single revolutionary moment, but have developed over a period. They therefore deserve to be labelled *evolutionary* rather than *revolutionary*.

Schwab's outlook is optimistic. He foresees that the 4IR will be life changing, as it "will fundamentally alter the way we live, work and relate to one another. In its scale, scope and complexity, the transformation will be unlike anything humankind has experienced before" (Schwab, 2015: 1).

Echoing Schwab, Gastrow elaborates further on the anticipated changes: "Humans, both individually and socially, are also changing. Notions of the human, and human interaction, are also undergoing multiple changes: increased longevity, augmentation of human bodies and minds, the changing nature of work, the changing nature of learning, changes to human connection and connectivity, and changes to identities, amongst others" (Gastrow, 2018: 10). Schwab's characterisation of the 4IR, signalling the far-reaching and unprecedented nature of the anticipated changes, constitutes the main argument for construing the phenomenon as a *revolution*.

A key characteristic of the 4IR is "a fusion of technologies that is blurring the lines between the physical, digital and biological spheres" (Schwab, 2015: 1). The disruptive technologies arising from the 4IR are anticipated to lead to innovation, impacting upon efficiency and productivity. It also has the potential to displace workers through greater automation (ibid: 2). For example, smartphone-enabled technologies will continue to create new ways to acquire goods and services, posing considerable threats to established and dominant businesses (ibid: 4). Schwab further elaborates that the unrelenting progression from digitisation, which characterised the Third Industrial Revolution (3IR), to innovation expected to emerge from a combination of technologies in the 4IR, impels leaders to understand the changing environment and respond appropriately (ibid: 5). He also sketches a vision for how citizens will engage with and interact with their governments using available and emerging technologies. He predicts that governments will harness technology to exercise greater control and surveillance over their populations (ibid: 5-6).

Consistent with Schwab's argument, Gleason (ed) (2018: 1) posits the following: "The automation economy, resulting from the technologies of the fourth industrial revolution (4IR), is changing the way we live and work." Other key characteristics of the technologies that underpin the 4IR are convergence (digital, physical, and biological); acceleration (exponentially increasing rate of technological change); and trans-humanism (expanding boundaries of what can be considered "human") (Gastrow, 2018:19).

As indicated above, the 4IR is sometimes confused or blurred with the 3IR (also known as the digital revolution), which has been well underway for years. Marwala provides a useful distinction between the two. He maintains that: "While the digital industrial revolution is about digitising our infrastructure, the 4IR is about reconstructing our infrastructure to be intelligent. While the digital revolution gave us computers, the 4IR gives us computational forms with which we can interact using speech. And whereas the digital industrial revolution automated production, the 4IR provides intelligent automation whereby machines can repair themselves. While the digital industrial revolution is based on digital computing, the 4IR blends digital computing with quantum computing, based on servers that use enormous amounts of information and less energy." (Marwala, 2020 (a): 12-13).

Compelling as the case has been for a 4IR, not everyone agrees with this characterisation of the phenomenon. Risking (2016) for instance, argues that the current phenomenon is merely continued digitalisation – a central feature of the 3IR, with no fundamental shift (in Jivan 2020: 7). However, Schwab's response to this critique is that "…the scope, speed and system-wide impact is qualitatively different to warrant the identification of a 4IR" (Jivan, 2020: 7). Clearly there are features of the digital revolution which have provided the foundations on which advances in the 4IR have been built, or where advances in technology and technological solutions have led to greater sophistication and unprecedented possibilities for the use of the emerging technologies.

Reinitz's position adds grist to the case made by Risking for characterising the phenomenon we are experiencing as a continuation of the 3IR. She distinguishes between *digitisation, digitalisation, and digital transformation. Digitisation* constitutes "transition from an analog to digital form," which entails putting "information online that was not online before" and organising it. *Digitalisation* entails "using digital technologies and information to transform individual institutional operations." (Reinitz, 2020:2). Commensurate with this is automating and streamlining of processes. Armstrong, arguing from a different vantage, point disagrees with this definition. He argues that *digitalisation* is "the process of dramatic change to the nature and conduct of business and its impact in the market and society" (Armstrong, 2018: 3).

Digital transformation (Dx) comprises "an institutional strategy to transform the strategic direction or value proposition of the college or university. Dx involves deep and coordinated shifts in culture, workforce and technology" which lead to institutional transformation (Reinitz, 2020:2). Debatably, the processes described are 3IR technologies that have increased in sophistication, reach, and spread. Whatever one's vantage point, for the envisaged change to be enduring and its impact sustained, *digital transformation* as described by Reinitz would appear to offer the most promising approach to leveraging the affordances of the 4IR.

The momentum towards the 4IR in South Africa received a boost from the work of the Presidential Commission on the Fourth Industrial Revolution (PC4IR), whose report was gazetted in October 2020. The report envisages the 4IR as having "the potential to catalyse South Africa's path to attaining the goals of the National Development Plan" (PC4IR: 137). Marwala (2020 (a)), who was Deputy Chairperson of the PC4IR, predicts, in agreement with Schwab, that the 4IR presages a "paradigm shift in every aspect of our lives." His recent book, (Marwala, 2020 (a)) covers a vast spectrum of areas anticipated to be impacted, changed, or that offer new possibilities through the 4IR. These include industry, business, and society. The use, management and leveraging of data will reach another plane.

While the potential pitfalls would concern anyone committed to social justice, there are ostensibly enormous benefits that can accrue for the economy, society, education, and future graduates. These will be explored next.

3. Benefits and Promise of the 4IR in Advancing Development

The connected policy interventions over the past decade such as the National Development Plan (NDP) (2011), PC4IR (2020), and the MTT (DHET, 2020b), all acknowledge the imperative for South Africa to have a coordinated and purposefully development-orientated approach to the future. The 4IR is forecast to have a potentially catalytic role. Gastrow, like others, (Gleason, 2018; Marwala, 2020 (a)), has also made a case for the momentous significance of what is unfolding before us in the 4IR, noting especially the potential benefits of the 4IR for development, and the need therefore to exploit its benefits

for this purpose. He contends that "The 4IR is seen as significant, imminent, and global. Being prepared for the 4IR means to position institutions in a way that the 4IR is harnessed for the benefit of human wellbeing, and in support of national and international social and economic benefits" (Gastrow, 2018: 10). This view accords with the NDP (National Planning Commission, 2011), and PC4IR (2020).

Peters provides an insight into the types of development-orientated technologies which are integral to the knowledge system in the 4IR. He calls these "[c]onvergent technologies". They consist of "nano-bio-info-cogno technologies … which enable each other and propel a vision of a science-based future," and furthermore, "have an accelerating impact and exercise a determining direction on economic and cultural development" (Peters, 2019). Corresponding with this, the NDP has already signalled an intention "to attack the blight of poverty and exclusion" (2011: 2) on many fronts, with an openness to all possibilities and avenues towards achieving the developmental goals of a society on a steep growth trajectory.

In the industrial sector, the changes underway are anticipated to be far-reaching. What is unique about the 4IR, as suggested by Xing and Marwala (2017), is that "[t]he 4th industrial revolution digitizes and vertically integrates processes across the entire organization" (2017: 11). A significant shift from the past according to their argument, is from merely processing products. In the era of the 4IR, production is "seamlessly integrated into the information network, the business partners and customers". Other benefits that flow from the 4IR are self-adaptive and intelligent automation from artificial intelligence (Xing and Marwala, 2017: 11). The benefits are anticipated not only for industry, but for organisations in all sectors.

To advance development objectives in the era of the 4IR, with the accompanying rapid change, how learning takes place needs to be rethought. This has been argued by Deloitte from an industry perspective: "In working to keep up with the pace of technological change, business leaders are also beginning to appreciate the need to nurture a culture of lifelong learning, equipping their workforces with the skills necessary to succeed in the future" (Deloitte, 2020: 2).

While technology has advanced rapidly with a commensurate expansion of computing capacity, the shift that suggests that a revolutionary change has occurred is that "vast amounts of data can be stored and processed to enable machine learning". The corollary is the development of cyber-physical systems, at the core of which are engineered systems and operations integrated by a computing and communication core, with the potential to transform the ways in which we interact with the physical world (Gleason, 2018; Rajkumar in Gleason, 2018: 2).

Automation is also anticipated to have a huge impact on jobs. Fraunhofer IPT, in a communique to their industry sector, claimed that "Inter-connectivity and adaptivity in production are forming a strong

foundation for Industry 4.0". Moreover, these are underpinned by "a new form of flexibility and adaptability of production processes and process chains which are self-adapting and optimizing" (Fraunhofer, IPT 2018: 5).

Research was undertaken at the South African Qualifications Authority (SAQA) "to consider how SAQA and the NQF will be positioned within the context of the 4IR, with a particular lens on the implications of the 4IR for the roles and responsibilities of SAQA" (Chetty, 2019: 8). She also found that "automation was raised as a key consideration by most respondents" (Chetty, 2019: 9). A key takeaway is that automation is anticipated to improve service delivery, quality, and cost-efficiency.

Another element of the 4IR is machine learning. It is a sub-field of artificial intelligence (AI), related to machines' capacity to learn inductively by processing data records and making inferences from these (Ally and Wark, 2020: 12). The benefit of this technology for enhancing learning can be quite far-reaching. "Machine learning in education can be used to personalize learning for each individual. The system will 'learn' about the learner as they progress, then make decisions that will optimize the learning" (Ally and Wark, 2020: 12). The potential for enhancing learning is similar with blockchain, another 4IR technology which "can be used to store individuals' learning and interaction history so that these can be used to prescribe the most appropriate learning materials and identify the help learners need" (Ally and Wark, 2020: 12-13).

It is projected that 50% of jobs in agriculture, forestry, fishing, and hunting, representing 328 million workers, are automatable. For manufacturing, the figures are 237.4 million; for retail 187 million; for the Chinese economy, it is 395 million jobs; for India it is 235 million; for the USA, 60.6 million (Gleason, 2018: 4, quoting a McKinsey Global Institute Report of 2017).

Clearly, while automation will have benefits for all types of production to cater for an ever-growing world population, the pernicious socio-political impact of the largescale loss of livelihoods for the world's poor and working-class must be attended to. In line with this, Gastrow has argued that the 4IR has a broader global socio-political aspect. This raises the question of considering in more depth the interplay between technological and social change (Gastrow, 2018: 23) and warrants an inquiry of its own.

Mindful of the constantly changing landscape, Deloitte encourages a proactive approach: "In this era of constant change and disruption, it is critical for organizations to develop and implement effective, holistic strategies that take advantage of Industry 4.0 technologies across their organizations" (Deloitte, 2020: 5). The Deloitte authors go further, proposing that organisations begin to gather data that will help them develop a deeper insight into the future so that their strategies related to Industry 4.0 are based on firmer foundations (Deloitte, 2020: 7).

4. Contested Possibilities of the 4IR

Much as a buoyant vision of a future heavily influenced by the 4IR has emerged in recent years, others, like Badat, (2020) caution against the pursuit of a "technocratic utopia", pointedly drawing attention to the swathes of the population who are yet to see the benefits of previous industrial revolutions, let alone the 4IR.

Writing an opinion piece in the *Daily Maverick* in response to Marwala's 28 May 2020 column in the same publication, "*Covid-19 has forced us into the fast lane of the 4IR super-highway*" (Marwala 2020 (b)), Badat sharply critiqued Marwala's propositions. In his article, Marwala addressed the pessimism about the 4IR among its detractors, including students, noting there are two camps – one acknowledging the promise of the 4IR, "a fundamental paradigm shift" where we are "on the cusp of seeing every facet of society change", while others "have dismissed the 4IR as a string of buzzwords whose currency remains largely unknown." He argues that the necessity to harness the 4IR is the more urgent as we deal with the pandemic and that a key feature which distinguishes it from previous industrial revolutions is that the "4IR is based not on a single technology, but on the confluence of multiple developments and technologies. It is already changing how we live, work, and communicate and by virtue of that is reshaping government, education, healthcare, and commerce". He provides several examples of how AI is changing healthcare; how it is integral to finding solutions to the pandemic; and how AI, big data, cloud technology, 5G related telecommunications technology, and remote working solutions, are changing the world of work.

Badat (2020) acknowledged that "New developments in knowledge, science technology and ways of economic production are the probable trajectory of the future". However, he warns of the insidious effects of post-Fordism on societies "manifest in rampant inequality and the massive accumulation of wealth and power in the hands of a tiny minority". He also contests Marwala's assertion of two camps, arguing that it is correct to question how 4IR is portrayed: "Given evangelical 4IR proselytising in some quarters, the students are quite right to question whether 4IR will be a 'magic wand' and to wonder whether it is 'overhyped'". He argues further that characterising the debate as consisting of two camps is too simplistic, and that there are probably many, one of which "would wish to pose and engage on many questions about the seemingly glorious utopia that 4IR promises". Central to his critique is that "4IR is viewed as an entirely scientific and technological matter, not as a social or human matter."

Indeed, a very real possibility in the onward march through the 4IR is an increase in unemployment and other regressive outcomes, instead of the anticipated upsurge in development and better economic prospects promised to those who advocate it. Paradoxically therefore, the 4IR poses huge threats to a society struggling to shake off the ravages of colonialism, apartheid, and under-development, and to

overcome the legacies of discrimination; chief among which are poverty, inequality, unemployment, and lack of access to opportunities as catalogued extensively in the NDP (2011).

Gillwald (2019), while observing the relentless advance of 4IR technologies, also sounds a warning about some of the consequences and what needs to be done to ameliorate them, especially inequality: "There is little doubt that the inevitable rise of the advanced technologies of artificial intelligence, blockchain and drones will disrupt economies and societies. But when this happens, the degree to which it will happen will be highly uneven. Like other industrial revolutions, this one will be characterised by evolution as much as by disruption. Unless something dramatically different is done, one of the continuities will be the perpetuation of inequality. And the primary determinant of inclusion is education and digital skilling" (Gillwald 2019). Indeed, the social justice imperative impels deep consideration of how the already disadvantaged and marginalised may be empowered to benefit from the 4IR, failing which the inequality gap is likely to widen.

While a good start at state level would be with progressive policies, policy solutions that focus on skills development as the remedy for a host of historical and structural conditions in our society may not be entirely to the point. Motala and Vally argue in this regard that "This ascendant discourse about skills has 'persuaded' policy makers to ignore the combination of social, economic, political and cultural factors which make the acquisition of knowledge and skills difficult for working-class and poor communities." They contend further that "The dominant discourse also downplays the impact of poor access to educational institutions and costs, locally-based educational facilities and infrastructure, pedagogical barriers arising from being taught in unfamiliar languages together with the relative powerlessness to intervene in ways that can counteract the weight of existing relations of power" (Vally and Motala, 2014: 4). The critique is echoed by Fataar: "The socio-technical imaginary that 4IR discourse installs is oblivious to the dynamics of educational inequality. Instead, 4IR is based on the view that closer attention should be paid to the vocationalisation of education and training. Skills acquisition is posited as key to educational reform in anticipation of producing workers who are able to work in a changing labour market" (Fataar, 2020: 4). Clearly the expectations surrounding the 4IR must be tempered by consideration of underlying challenges and conditions of inequality, and how they are likely to be impacted in the forward march of the 4IR.

While HEIs grapple with how to equip graduates for the future, employers have their own related challenges on how to remain competitive while harnessing the affordances of emerging technologies, which may well have negative consequences for jobseekers. Peters' assessment is that the future of work looks bleak. Fewer jobs can be anticipated with more competition and lower wages: "all signs indicate that the theoretical principle of the infinite substitution of capital for labor has arrived in applications of AI to labor processes in factories, offices and university research" (Peters 2019).

In a different vein, Gastrow warns about the adverse effects of technology in the exercise of power: "New technologies are important to the future of power, and in some cases pose existential risks to humanity. For example, artificial intelligence (driven by machine learning technologies) is being used by the military, intelligence, economic, and public sphere areas" (Gastrow 2018: 10). So, while livelihoods are threatened and job losses occur, 4IR technologies also provide state and economic actors with greater capabilities and instruments of control, surveillance, exploitation and even oppression. The net result may be an erosion of hard-won freedoms, and greater exploitation of the masses, rather than the enriched lives and enhanced possibilities that have been advocated as imminent from the 4IR.

In view of the many warnings that have been sounded, some of which have been captured above, it is apparent then that a very real possibility is that advances in the 4IR could lead to an increase in unemployment and poverty, deepening inequalities, more state control, and more pervasive economic exploitation of individuals and communities through the tools available to actors controlling the levers of economic and political power. These possibilities stand in stark contrast to the upsurge in development, better economic prospects and achievement of development goals promised from an embrace of the 4IR, as detailed in the National Development Plan (2011) and PC4IR (2020).

In a prescient observation, Jensen warns of the cost of neglect of the social justice imperatives, and the responsibility that therefore falls on HEIs: "When technology is not available equally to all, we refer to digital divides, but the main issue is rather the creation of 'knowledge divides', resulting in different and unequal opportunities to act, take part in and develop society. Higher education institutions are at the heart of knowledge creation and dissemination; it is therefore only natural that higher education takes an active part in shaping a knowledge society" (Jensen, 2019: 53). As institutions in society with immense capacity to inform, support and advocate for social justice, HEIs will be failing in these duties should they not give due attention to issues of access to and availability of technology to the poor and marginalised.

5. The Potential for Tertiary Education, Teaching and Learning

Technology in higher education has become an increasingly strategic priority for governments and universities. The International Association of Universities (IAU), with its approximately 650 member institutions, anticipated that technology in higher education would have implications for the future development of both higher education and society (Jensen, 2019: 8). During 2018 it therefore embarked on a major exercise to develop a policy statement on the subject. Consultations were held with higher education leaders from just under 700 institutions from 106 countries (Jensen, 2019: 9).

Jensen describes persuasively how the world is expected to transform because of technological change, and how HEIs need to respond: "technological advancements have an impact throughout the world on the everyday lives of citizens, on how societies are developing, on the skills and competences required

to take part in society; and most importantly, on how to access information and knowledge. Although the transformations are taking place in different ways, at different paces, and with different means and opportunities, one factor common to HEIs is that they are all confronted with the question of how to adapt and shape higher education in an increasingly digital world" (Jensen 2019: 51).

Policy and regulatory reforms in South Africa aimed at harnessing the 4IR to achieve national development goals are clearly signaled in the PC4IR Report (PC4IR, 2020: 161). Driving the 4IR initiative at the national level will be a Digital and Future Skills Forum which is likely to provide guidelines for curriculum reform and projections of the types of skills and competencies required for the future world of work, to enrich students' lives culturally and intellectually and to broaden learning beyond the formal curriculum. Curricula will have to be geared to developing the digital skills which are critical for employment and for an enriched and fulfilling life in the 21st Century. Fundamental questions about the relevance, adequacy, and responsiveness of current curricula to the 4IR and the future world of work will no doubt loom large.

More sophisticated use of digital technology in tertiary education is called for, starting with the 3IR technologies, the current spread of which is uneven in our society, in administration, teaching, learning support, and e-learning. Online data and information management; aggregation of vast amounts of data; and analyses of data for student success and student support promise a positive impact on success and throughput rates. A range of possibilities open up for more frequent assessment opportunities, and for regular mediation of learning through online learning management and assessment systems. In line with these possibilities, du Preez and Sinha make the case for post school education at the very least to "adapt to the changing nature of work, and ideally, lead this evolution" (du Perez and Sinha, 2021: 13). South African HEIs are no doubt attending to all these imperatives, hastened in great measure by the Covid 19 pandemic of 2020 that led to most teaching and learning activities shifting online.

Institutional investment in relevant 4IR related infrastructure, changed IT solutions, capacity development, and revised business processes must move in tandem with student access to devices and affordable access to the internet. On curriculum, the 4IR Commission Report signals clearly what needs attention for sectoral alignment with national developmental goals. This includes skills and qualifications as well as capacities aligned with employment opportunities (PC4IR, 2020), more flexible qualification options, and more innovative ways of recognising and credentialling learning, with implications not only for curriculum reform as outlined above, but also for regulation, quality assurance and accreditation of programmes. Taking all of these into account, the PC4IR Report states that "The 4th IR gives us a rallying point of urgency and an opportunity to redesign, streamline and align the education system through a coordinated, robust, multi-stakeholder process. The purpose of the next version of our skills ecosystem will be to leapfrog our youth into productive work and reskill current workers for job retention and ongoing productive work in the economy."

While the potential benefits of 4IR are appealing, and hold great promise, a variety of enabling conditions need to be established at the national and institutional levels before tangible benefits are realised. As argued earlier, chief among these is the necessity to fully harness the benefits and possibilities of the 3IR and ensure that they are accessible to those who are currently marginalised and cannot afford access, or where required infrastructure has not reached them. At the institutional level, concerted efforts need to be made for a decisive and comprehensive programme of digitisation where this has not yet been achieved optimally.

It is apparent from information that emerged during the Covid19 pandemic locally that while several institutions have been very well-geared for the switch to emergency remote learning and online teaching, many have struggled and have a considerable way to go to reach acceptable levels. The biggest barriers for students have been access to devices, affordable data, and accessible infrastructure. The adjustment to the new modalities has been surprisingly well received nonetheless as the SAULMS Report (DHET, 2020 (a)) reveals. Barriers to the 3IR will continue to be constraints for the 4IR. Going forward, there are many changes that existing and new technologies demand. Caught as we are in the overlap between the 3IR and 4IR, national and institutional policies must be purposeful and realistic, with adequate allocation of resources and carefully conceptualised programmes which capitalise on the benefits of the 3IR fully, while making the required interventions to leverage and build upon advances in the 4IR in the future.

Most higher education institutions have made progress within their resources and capabilities in responding to technological change. Czerniewicz et al (2021: 12) state that large-scale changes are taking place that are reformulating the narrative of higher education and its *raison d'etre*: "On a professional level these changes are producing emergent forms of teaching and learning and question academic roles with regard [to] who has ownership and control over the teaching and learning process. These changes are affecting and are affected by academics and their agentic action" (ibid: 12).

Czerniewicz et al (2021) also illuminate other forces of change observable in the higher education sector that are corollaries to technological change and the 4IR. They argue that marketisation (entrepreneurial competition), digitisation (educational provision mediated by digital technology) and unbundling (disaggregation of educational provision into component parts through technology-based partnerships with private providers) are also impelling new forms and models of teaching and learning in higher education (2021: 1-2). Their study found further that "there is no consensus and there are polarized views (in the contexts of South Africa and the UK) about the value of digitally-mediated forms of provision" (Czerniewicz et al, 2021: 10). These findings cannot be ignored. They signal the need to sift what is realistic for and advantageous to the educational process, from the sometimes near-evangelical promotion of technological solutions that are resource intensive and ever more complex.

One of the key observations of the NDP is the high cost of access to the internet, which has a constraining effect on the national march towards a digital future. Nonetheless, the intention of universities to advance to this future is clear, requiring a focus on research and development, knowledge production and innovation towards "world class centres of excellence at the cutting edge of technology." A further clear intention is to align institutions with the needs of business: "Public resources should be targeted to build the research infrastructure required by a modern economy in line with the country's development strategy" (NDP, 2011: 9).

In education, more sophisticated use of digital technology for administration, teaching, learning support, and e-learning has a discernible impact on the quality, efficiency, and success of higher education. Online data and information management; aggregation of vast amounts of data; and analyses of data for student success and student support have been shown to have had a positive impact on success and throughput rates. A range of possibilities has been opened for more frequent assessment opportunities, and for regular occasions to mediate learning through learning management systems.

Xing and Marwala (2017) go further and identify several anticipated impacts of the 4IR on higher education. They see potential in wearable technology to "revolutionize the way we teach and train students and how they learn as well." Augmented reality will enable "creating a virtual laboratory." Much as the technologies show a lot of promise, they are still to be adequately tested, for initial indications are that they may not be as interactive as desired, while also being quite isolating.

Xing and Marwala (2017) also see the potential of Massive Open Online Courses (MOOCs) to overcome the constraints and costs imposed by requiring students to gather in lecture halls with a lecturer. MOOCs overcome these limitations through off-campus, online modalities of teaching and learning (ibid: 2017). Du Preez and Sinha also see the potential of MOOCs in that this paradigm "eliminates the requirement for physical proximity to deliver lectures." They also acknowledge their benefit in increasing access to larger numbers of students without corresponding physical infrastructure requirements (2021: 15). The optimism about the potential role of MOOCs must nonetheless be tempered by the reality that they have had relatively low completion and success rates, as has been widely publicised.

Others have made arguments which echo those of Xing and Marwala. 4IR technologies "are being applied to holistic, immersive learning environments, as well as in MOOC settings to provide immersive MR[mixed reality] learning experiences" argue Ally and Wark (2020: 11), leading to considerably enriched and enhanced learning experiences for students, providing "real-life situational experiences, which can enhance student or trainee motivation, engagement and interaction, yielding deep, meaningful learning results." Moreover, they argue that "Teaching/learning factories and MOOCs are increasingly merging remote labs, virtual representations of workplace settings and labs, AR/RAR/VR

[augmented reality/remote augmented reality/virtual reality], other mobile devices, and additive manufacturing technologies to produce life-like scenarios and experiences aimed at developing the knowledge, skills and attitudes necessary to live and flourish in the mixed-reality environment of the 4IR era (Ally and Wark, 2019a, 2019b; Block et al. 2018; Grodotzki et al. 2018; Mavrikios 2019; Mourtzis et al. 2018)" (Ally and Wark 2020: 11). In the final analysis, the use of ICTs must lead to improved student engagement and learning experiences, as proposed by Mishra and Panda (2020: 4). The OECD has also acknowledged the advances made in digitisation, the associated development of MOOCs, and their potential to promote lifelong learning (OECD, 2019: 133).

Marwala advocates that we "shift the focus from teaching to learning, with emphasis on real-world problem-solving abilities and a multi-disciplinary approach to curricula that are more interactive. In tandem with traditional classroom learning, there is a move towards including student engagement through peer-to-peer interaction and one-on-one counselling that holds great promise for students. This form of cooperative education and co-construction of the teaching and learning process is very much part of the 21st-century university" (Marwala, 2020 (a) :158).

Given the many obstacles related to infrastructure, cost-effective data, and access to devices, which have emerged regularly in diagnostic analyses such as those done by the NDP and PC4IR, it is encouraging to note that the IAU study indicates that technology is being substantially integrated into teaching. For African universities that were part of the study, 38% of respondents indicated this is happening very much, while 49% indicated that it is happening to some extent (Jensen 2019: 29). While there is yet a considerable way to go, progress is noteworthy.

Universities are themselves changing. Williamson and Hogan contend that there is a decisive shift in the ideal of what a university should be: "The ideal of the knowledge-intensive university of the twentieth century – which conducted research to produce new knowledge, transmitted it through teaching, and created value for the knowledge economy, has gradually shifted to an ideal of the 'data-intensive' and 'digital-first university' of the twenty-first century that creates valuable new digital knowledge and develops digital data skills to support emerging capitalist data economies." (Williamson and Hogan, 2021: 13, referencing Berry, 2020). The changing ideal is not unproblematic as pointed out by Selwyn (in Williamson and Hogan (2021:14): "These ideals of the digital university favored by policy makers and policy influencers also emphasize neoliberal logics of economics, efficiency, competition, audit, accounting, performance measurement, quality management, marketization, commercialization and privatization (Selwyn, 2014)".

The spread, reach and impact of purposeful technologies and services aimed at higher education are clearly underway as pointed out by Williamson and Hogan: "The global industry of educational technologies and data services has grown to encompass every aspect or 'market segment' of HE activity,

including: recruitment, enrollment and admissions services; student management systems; core digital infrastructure; management dashboards and analytics platforms; learning management systems and virtual learning environments; digital library and information services; learning software and courseware; learning analytics; online assessment; plagiarism detection; graduate talent analytics; alumni and graduate relationship management; and more" (Williamson and Hogan, 2021: 15). The benefits in terms of efficiency gains, greater reach in recruitment, simpler business processes, and enhanced learning support for students, amongst others, cannot be denied, much as more pernicious effects have also come to light and require due attention. These include increased unemployment flowing from automation, a widening digital and knowledge divide as argued earlier, and greater intrusion on the privacy of citizens as data on individuals is collected and mined by state and commercial players, amongst others.

6. Implications for Curriculum

A central purpose of higher education is to cultivate the potential "to develop capacity for academic achievement and retention of knowledge among graduates to prepare them for a productive life" (Gleason, 2018: 5). Marwala has made a convincing case for universities to reform their curricula with a particular focus on equipping their graduates for the changing world of work. This would entail a review of modules and qualifications, working closely with industry to ensure that the curricula are responsive to its needs as the world becomes more automated (2020 (a): 22). There should be due caution in ensuring that the economic imperative does not overshadow the social and the environmental.

The faultline that Fataar has identified goes to the very foundations of the conventional curriculum: "The focus of the 4IR curriculum is to emphasize generic skills and student learning, and its de-emphasis of disciplinary learning, concepts, and content knowledge means it falls into the trap of what Maton (2014) has called knowledge blindness" (Fataar, 2020: 16). His critique draws attention to the neglect of knowledge and concepts, resulting in such curricula failing to provide students with the concepts which form the foundations for ongoing acquisition of the more comprehensive knowledge for which he argues. Moreover, both Fataar (2020), and Vally and Motala (2014) suggest a reconsideration of the fundamental role and purpose of universities – an apposite question in the face of large-scale change triggered by external forces of the kind alluded to above.

How curricula change in response presents its own challenges. Responsiveness to the changing nature of knowledge and the world of work, to equipping students with digital skills, and to the often narrow needs of industry may well lead to greater instrumentalisation of higher education, especially when this is coupled with a new approach to credentialling, featuring stackable qualifications and the micro-credentialling referred to below. Those trying to reform curricula should also not lose sight of multi-

disciplinary approaches to addressing global challenges such as climate change, pandemics, poverty, inequality, development and ethics, to name a few.

An impetus in the direction of multi-disciplinarity is already gaining momentum. Marwala observes that "With the demands and challenges of the 4IR, there is now a move towards new, flexible, often multi-disciplinary curricula that steer away from the traditional focus on predefined categories and types of learning" (2020 (a): 156-157). A constructive and forward-looking medium between the two positions is needed.

While we must be mindful of criticisms and attend to their implications for curriculum development and reform, Fry and Tinson assert that "with industry 4.0, we are now also entering the age of education 4.0, where we must constantly adapt to prepare our students for the changing landscape of the job market. Having increasingly more contact with various types of technologies will help them develop the skills they will need for their future roles and serve as the stepping-stone in equipping them for the next waves of digital innovations, which will certainly keep coming" (Fry and Tinson 2019: 2).

The PC4IR Report also considers the curriculum. The report signals clearly what might require attention to promote sectoral alignment with national developmental goals: skills and qualifications, in particular capacities aligned with employment opportunities; more flexible qualification options, and more innovative ways of recognising and credentialling learning, with implications for curriculum reform as well as for regulation, quality assurance and accreditation of programmes. The report reflects an ambitious vision for the future intended to "leapfrog our youth into productive work and reskill current workers for job retention and ongoing productive work in the economy" (PC4IR, 2020: 173). In the short-term urgent action is required in areas such as redesigning, streamlining, and aligning the education system (ibid: 173). It also envisions that "The skills demand of the 4IR era require stackable competencies which are micro-credentialled, industry-aligned and allow people to enter and exit the system at multiple points as part of a lifelong learning process" (ibid: 173).

Clearly as the proposals take shape as policy and are executed, unintended consequences that detract from the role and purpose of universities must be guarded against. Potential threats are greater vocationalisation of curricula, and the development of a tiered higher education system, with higher order knowledge for the elites and practical vocationally orientated knowledge for the masses.

The MTT on the 4IR made similar findings and proposals to the PC4IR Report. It identifies a range of interventions required to reform the PSET system: "The PSET system should be re-oriented to provide for a wide range of teaching and learning approaches and strategies, according to need. Such an approach requires flexibility in admission criteria, curriculum design, learning and teaching modes, and assessment, with appropriate support systems and services across the PSET sector but also within sub-

sectors. While these imperatives are not triggered by the 4IR itself, 4IR technologies offer new possibilities and present new challenges that must be considered in strategic, policy and regulatory options related to accreditation. This should lead to more flexible quality assurance systems, both at institutional and national levels which are capable of assuring quality across a wider range of educational modalities with fewer common key indicators of quality. … [A]gile education and training require accreditation to happen quickly" (DHET, 2020 (b):10.)

The MTT also examined the changing landscape of the world of work, with new types of technology-related capabilities, skills, and roles in the workplace, including data analysts and scientists, software developers, and e-commerce and social media specialists. Other workplace roles are specifically 4IR-related in the fields of AI, machine learning, process automation, blockchain and others (DHET 2020, (b): 24). A responsive higher education system is required that will take proactive steps to ensure provision in the areas identified, and in areas which will likely emerge in the future. The MTT spelled out a new vision for the PSET system, a key element being a core of education and training programmes aligned with the changing needs of South African society that ensures "Access to high-quality educational opportunities that meet a burgeoning and immediate demand for 'digital skills' in the labour market created by the 4IR ..; Massive increases in short-course learning opportunities for unemployed and underemployed South Africans ..; [and] Growing emphasis on integrating into PSET programmes and courses learning opportunities that prepare people to be able to cope with accelerating change, both socially and economically, and thus emphasise key generic skills such as problem-solving, critical thinking, advanced literacy and numeracy skills, oral and written communication skills, the capacity for ethical reasoning, and the ability to work effectively in teams, among others" (DHET, 2020 (b): 37).

In its survey, Deloitte found a similar recognition among executives on the future skill and capacity needs of industry, with a growing awareness that training and development needs to be responsive to Industry 4.0 (Deloitte, 2020: 11).

The adequacy of today's higher education to cater for Industry 4.0 and the 4IR has been questioned by Gleason: "today's higher education was designed to meet the needs of past industrial revolutions with mass production powered by electricity. Those systems are not suited for the automation economy" (Gleason 2018: 5). Others have detected a sea-change in the understanding of what the labour market requires in the 4IR era. Vettori and Gover for instance argue that "Institutions, students and employers are placing increasing attention on transversal, in addition to subject-specific competences, particularly as the employment market becomes more fluid. As the labor market changes, so do expectations regarding the type of transversal skills needed by graduates" (Vettori and Gover, 2020: 4).

In its analysis, the MTT gauged that the capacity and appetite of the PSET sector to fully realize the potential of the 4IR is not optimal currently. In particular, "It is not able to offer PSET opportunities on

the scale demanded by a knowledge economy. Current curricula, programmes, and courses are misaligned with labour market demands, while mechanisms to review and update programmes and curricula are highly bureaucratic and operate in long, slow cycles" (DHET, 2020 (b): 35). This analysis signals the need for sustained effort to reach a state of optimal responsiveness and capability, beginning with a review of the extent of the perceived misalignment, and devising approaches to narrow the gap.

Research by SAQA also revealed a concern about the relevance of qualifications: "It was reported that qualifications in 4IR areas would need to be registered and re-designed. Qualifications would need to accommodate both 4IR skills and 'soft skills'" (Chetty, 2019:10). The need to review and align curricula to cater for future needs of society were stressed in the MTT report as well: "New skills will be required to create, maintain and leverage these new [4IR] technologies. This will require the formal post-school education and training [PSET] system, working in partnership with government departments and employers, to repurpose and reconfigure curricula considering lifelong learning and the need for a broader and more agile PSET system to respond to skills needs as they arise" (DHET 2020 (b): 26-27)).

In summary, a common theme in the foregoing analyses and proposals for the future are the need to review and reform curricula to render them more relevant, responsive, and aligned with the future needs of our society as it navigates the 4IR.

7. Enabling Conditions

It is anticipated that the 4IR can have quite negative consequences for employment. In this regard, Marwala characterises the future as follows: "This era of the 4IR will be a post-work one, because the need for humans in the workforce will be severely curtailed, effectively changing the face of labour" (2020 (a): 130). Nonetheless, opting out of the (4IR) revolution is not advisable: "Either we participate, or as a country we are economically obliterated, relegated to the 'dustbin of history'" (Marwala 2020 (a): 130).

While the potential benefits of 4IR are tantalising, and even hold immense promise, a range of enabling conditions needs to be established at national and institutional levels before tangible benefits can be realised. First among these is the imperative to fully harness the benefits and possibilities of the 3IR, many of which are the *sine qua non* for the 4IR. Central to this quest is to bring the marginalised and unreached into the fold through cost-effective access to the benefits and technologies of the 3IR. As indicated earlier, evidence shows that the Covid 19 pandemic has had a discernible effect on higher education. According to Atherton, "The pandemic may only serve to exacerbate existing inequalities in higher education participation and attainment. Evidence shows that such inequalities are universal. Research undertaken in 2016 showed that in all countries where data was available (over 90%) inequalities in participation existed by social background" (Atherton, 2020: 1). The primary issue has been identified as digital connectivity, without which students cannot adequately prepare for or take

examinations (Atherton, 2020: 2) since most institutions shifted all activities online during the pandemic.

Measuring success in the use of technology for learning, and students' openness and receptiveness to its use, is an important factor even before provision of devices and connectivity are considered. The Covid19 pandemic has had a catalytic effect in exposing many students to online delivery, support, and assessment, with the benefits of these modalities demonstrating clear advantages. A degree of satisfaction is evident from the remote teaching and learning experience of students in the DHET Survey during the pandemic. A significant proportion of respondents in the survey indicated that the learning materials had provided clear learning outcomes (65%); given access to relevant content (69%); explained new content and concepts carefully (60%); been well organized and sequenced (61%); and provided activities to engage critically (61%), amongst others (DHET, 2020: 34). What these findings unmistakably signal, capacity notwithstanding, is the readiness of most public HEIs to make a decisive shift to online learning and learner support, and a growing receptiveness among students to these changes.

Undoubtedly, more investment is needed and progress achieved in digitisation of all learning materials, to maintain the momentum created during the pandemic. The picture that emerges from the DHET study however is encouraging, demonstrating that institutions are on the right pathway. To reach optimal levels, the evidence is that the numbers to be targeted and the gap to be filled may not as large or onerous as might be assumed. However, institutional and individual staff capacity may not measure up to this promise.

While we are yet to establish its impact on learning and success, the DHET survey has shown that many students have made the transition to the online learning mode and are utilising it for a range of learning, communication, and assessment purposes, amongst others. A total of 92% indicated they use the online avenue to submit assignments; 78% for downloading materials; 76% for writing tests; 73% for email communications; 71% for accessing learning materials online; and 70% for participating in online chats with classmates. A further 43% used the mode for attending virtual lectures (DHET, 2020 (a): 29).

While the focus above has been on students and their adaptation to the online modality, academics and learning support practitioners have a similar responsibility. In this regard, Menon and Castrillon observe that "If HE is to prepare students for the challenges of the 4IR, a more rigorous engagement is required by all academics across the board – cutting through silos – innovative pedagogies that enable students to become independent learners outside the confines of the lecture halls" (Menon and Castrillon, 2019: 11).

Other hurdles will need to be overcome for the benefits of technology-enhanced learning to be fully realised. In a survey of fifty British universities for instance, Fry and Tinson state: "Our study shows that the three biggest barriers for digital delivery is (sic) organizational culture (70.45%), financial constraints (47.73%) and lack of capacity or capability in IT (40.91%)" (Fry and Tinson, 2019: 12). Variability in internet penetration is yet another barrier (Atherton, 2020: 3). There is a high probability that these barriers are present in our context as well.

Identified here has been the range of enabling conditions which need to be either created or improved to be adequately responsive to the possibilities and promise of the 4IR.

8. Imperatives for Change flowing from the 4IR.

As detailed above, 4IR progression has been predicted by several commentators and analysts, as well as policy makers, to increase in momentum and depth. Gastrow observes that what we are likely to experience is "technological change as a broad and accelerating process" (Gastrow, 2018: 17). Several consequences for strategic, policy and systemic (including educational) change flow from this realisation. Du Preez and Sinha (2021) remind us of the inadequacy and limitations of higher education systems during previous industrial revolutions, when the imperative to develop new disciplines in response was incontrovertible. They indicate that we find ourselves in a similar situation in the context of the 4IR (2021: 14). They caution us not to be slow in responding to the sea-change prompted by the 4IR, and to recognise the need for change it demands at all levels - state, sectoral (higher education and industry), institutional, and individual.

Digital technologies are expected to play a greater part in all progress in this area. This preoccupies policy makers and thinkers in both the developed and developing world. In this regard Jørgensen contends that: "innovation and use of new technologies is increasingly seen as a geopolitical challenge, where the dependence on American or Chinese technology is seen as a threat to Europe's sovereignty. If Europe has too few citizens with digital skills, particularly those that develop new technologies, it would be completely dependent on imported technologies" (Jørgensen, 2019: 4). Similar anxieties have been signaled in Denmark: "The introduction of ICT has been prioritized more highly in Denmark: politically, strategically and economically. The use of ICT in higher education was placed at the centre of the political agenda as early as 2007, where a 'more ambitious' use of IT was made an explicit goal for the government of the time" (Tømte et al., 2019: 109). The same concerns would apply in the context of a developing country such as South Africa.

In line with these imperatives for change, Marwala argues for a more adaptable education system. He provides a glimpse of how universities need to adapt, suggesting that our degree programmes need to be restructured to respond to the demands of the 4IR, much as a feature of curriculum reform before the advent of the 4IR had been to address the changing knowledge needs of society. "To acquire a broader

range of skills," he says, "students need the freedom to choose courses outside of a programme, and universities must respond to this" (2020 (a): 23). One example of this, consistent with the recommendations of the PC4IR outlined above, is visible in the option for students of "stackable degrees – which are comprised of courses or modules from diverse faculties and disciplines that are stacked together to form an academic degree – through multiple entry and exit points and by using technology such as data analytics to develop customized learning paths" (2020: 23). Zeleza and Okanda (2021) expand on the range of necessary changes, going beyond academic structures, that confront African universities: "digital transformation must be embedded in institutional culture, from strategic planning processes and organizational structures to administrative and daily operational practices, while avoiding exacerbating existing digital poverty for historically, socially, and spatially disadvantaged communities" (2021: 2).

How we need to adapt as a society, economy, and as institutions in the context of wider transformation is echoed in the MTT report: "It is this intersection between the technology revolution, a transforming society, and radically new ways of doing business and governing that make 4IR so disruptive and transformative. As a country, South Africa needs to identify and excel in targeted areas of technical and scientific disciplines that best align with the South African development agenda (DHET, 2020 (b): 21). While the emphasis on STEM disciplines is understandable for the concern with national competitiveness, a necessary caution is that this should not happen at the expense of the social sciences and humanities.

Institutional investment in relevant 4IR related infrastructure, changed IT solutions, capacity development, and revised business processes must move in tandem with full student access to devices and economical access to the internet. Skills development for students needs to focus on how to enhance their use of the internet for learning purposes, to enrich their lives culturally and intellectually and to broaden learning beyond the formal curriculum. These are some of the affordances of technology flowing from the 3IR. Gastrow also argues for "strengthening the interactive capabilities among institutions of skills supply." This requires:

- Cultivating the capacity of post-school education institutions to engage with employers and understand their current and potential future skills requirements (which change along with technological change).
- Shortening the cycle for curriculum change to respond to changing technologies.
- Cultivating a research agenda that senses technological change and responds accordingly (Gastrow, 2018: 26).

The orthodoxies which currently shape higher education at all levels, including how programmes and qualifications are structured and regulated, how they are quality assured, how learning credits are

accumulated, and how ongoing learning takes place in the era of the 4IR, all need fundamental rethinking. According to Barber, technology, and the competition that emanates from it, are anticipated to threaten many aspects of the traditional university, implicitly warning it to remain or become efficient, economical, and attractive (Barber et al., 2013: 32). Gleason's cogent arguments are consistent with this. He lists some of the emerging issues that require attention: "Traditional, undergraduate, graduate, and research education will remain important to society, but space must be made for adult learners to continue their learning as well. … The concepts, let alone the vernacular, are nearly all new. From micro-credentials, Education 3.0, nano-degrees, adaptive learning, micro learning, upskilling, to the idea of preparing for just-in-time education, the message is that we must all keep learning" (Gleason, 2018: 6).

As argued earlier, many obstacles need to be overcome if the potential of the 4IR is to be realised and the required curriculum reform is to be put in place. One of the critical barriers has been identified in the MTT report: "Further complicating curriculum responsiveness is the rigid, slow and arduous processes of quality assurance and programme accreditation at institutional and national levels. The policy environment is at best unreceptive, and at worst hostile, to a more agile credentialling system" (DHET, 2020 (b): 34). The agencies responsible for these functions such as SAQA and the CHE are required to be responsive and adaptive as well. Menon and Castrillon have provided a cutting critique of the current regulatory and quality assurance system, and the imperative for change that is implied: "This compliance-heavy system, coupled with the assumption that education means skills which correlate to programme 'outcomes' at a certain defined level, means that a thorough reversal or re-imagination of the nature and form of higher education may be needed to prime the system for the 4IR and make a discernible impact on the employability of students in the system" (Menon and Castrillon, 2019: 7-8). The current unagile, bureaucratic and inflexible regulatory and quality assurance processes have the effect of frustrating institutions in responding to emerging societal needs with the necessary dexterity (Menon and Castrillon, 2019: 8).

Attention to the issues identified above must be tempered by the realisation that the interventions are not a panacea for resolving the spectrum of development and legacy challenges that dog the development agenda. In this regard, Vally and Motala caution that: "We argue in essence that education might increase employability but is not an automatic guarantee for full employment; that an instrumentalist view of the role of education is unhelpful especially as such a view is always based on a raft of unjustified claims about the outcomes of education and skills in capitalist societies; that education and training is not simply a handmaiden for resolving the problems of low economic output; and that a wide range of exogenous factors and social relations (inherent in all societies) circumscribe the potential value of education and training." (Vally and Motala, 2014: 31-32).

With a constantly shifting 4IR landscape, it is difficult to predict what skills and capabilities will be demanded from graduates once they have joined the world of work. Jørgensen suggests proactive measures: "One way that universities are meeting this challenge is to change the content of their teaching (including lifelong learning), adding new study programmes and new curricula, including data literacy. This can include common courses in basic digital literacy for all students" (Jørgensen 2019: 6).

Finally, it must be pointed out that the challenges of change and adaptation do not only fall on the shoulders of policy makers and higher education institutions. Individuals need to adapt as well and develop resilience in the context of a changing, increasingly complex, and uncertain future. Barber has argued how to do this: "We need citizens ready to take personal responsibility both for themselves and for the world around them: citizens who have, and seize, the opportunity to learn and relearn throughout their lives. We need citizens who are ready and able to take their knowledge of the best that has been taught and said and done and apply it to the problems of the present and the future" (Barber et al 2013). Marwala also argues compellingly in this regard for the responsibilities of individuals and institutions alike: "As a matter of national culture, people and sectors from across society must be prepared to reskill and to approach upskilling as a continuous process. The education system at all levels must promote problem-solving skills, computational thinking, multi-disciplinary skills and systems-thinking, while equipping our students to master the social, economic and political worlds" (2020 (a): 27).

9. A Supportive Infrastructure, Access to Devices, and Cost-Effective Connectivity

Critical to the success of the 4IR in South Africa is the national infrastructure to support it. Marwala poses the central dilemma frankly: "How can we possibly focus on the 4IR when we are still struggling with the second industrial revolution?" (2020 (a): 58).

South Africa is in the early stages of preparedness for 4IR, while 20 countries already have AI strategies in place (Marwala, 2020 (a): 25). Encouragingly, a high percentage of institutions on the continent of Africa indicate that student enrolment is undertaken online. A total of 53% indicate that this is fully online, while 37% indicate that this is somewhat true for their institutions (Jensen 2019:26). This is higher than expected given the resourcing and national bandwidth infrastructure challenges in many African countries. Reinitz cautions that "Simply putting courses online or implementing a more modern enterprise system isn't digital transformation." To be truly transformative the effort needs to be in depth and coordinated, bringing under scrutiny the whole architecture of the organisation from its strategy, to value proposition, and business model (Reinitz, 2020:1).

The IAU study illustrates the stark inequalities in terms of access to the internet for Africa compared to the rest of the world. In Africa, 24.4 individuals used the internet per 100 in 2018, compared to 45.3 in the developing world and 80.9 in the developed world (Jensen 2019: 16). Only 7% in Africa considered

the internet infrastructure as very satisfactory, with 39% indicating that it was good in big cities but poor in rural areas (Jensen, 2019: 17). These figures suggest a huge stumbling block in the way of harnessing the affordances of technology and progressing at a sufficient pace in the 4IR.

In South Africa, the DHET survey reveals that 96% of students surveyed report ownership of a device with 90% reporting that they owned one or two devices. Of these, 60% had laptops. The vast majority owned a smartphone (89%) (DHET, 2020 (a): 23). Students are also using a variety of devices to access learning – 4% use a desktop computer, 58% a laptop, 7% a tablet and 89% a smartphone (DHET 2020 (a): 24). This signals that the availability of devices that could be used for remote learning and for e-learning generally is already quite high. It is also apparent that a variety of avenues have been utilised to secure devices. This ranges from purchase by self (33%); purchase by a family member (36%); receipt as a gift (10%); provided by the university (added to fee account) (8%); purchased with NSFAS allowance (33%); and provided as part of a loan bursary (3%) (DHET, 2020 (a): 25).

Only 50% of students reported that there is good connectivity where they are studying (DHET, 2020a: 28). Most students surveyed in the DHET study indicated that they bought bundles from service providers for their online activities (62%). A total of 46% indicated that they utilised free access through the university. Smaller percentages utilised alternative avenues – public Wi-Fi (8%); home facilities (16%); monthly SIM contracts (9%); hot-spotting off someone else (23%) (DHET, 2020 (a): 31). The dependence of a large proportion of students on their universities to provide Wi-Fi access is quite significant. Commercial costs of data remain prohibitive for most students – indefensibly, being among the highest in the world. This needs to be ameliorated as it has persistently constituted a barrier to students using online modalities for learning, communication, and support.

Institutional infrastructure may also be quite uneven. The IAU study reveals that 24% of institutions in Africa report that they are using learning management systems fully compared to a global average of 35%. A further 46% indicate that they are using LMSs somewhat, and 19% report that it is being discussed. Only 11% indicate it is not on the radar at all (Jensen, 2019: 27). While the figures for South Africa may be higher, they still lag significantly compared to the rest of the world. The IAU study established that less than half of respondents indicated that the national regulatory policies were either supportive or conducive for Africa. A total of 56% of respondents found that national regulatory policies were either variably supportive or mostly unsupportive (Jensen, 2019: 14).

The challenges to the PSET system are aptly summarized in the MTT report: “The PSET system should be re-oriented to provide for a wide range of teaching and learning approaches and strategies, according to need. Such an approach requires flexibility in admission criteria, curriculum design, learning and teaching modes, and assessment, with appropriate support systems and services across the PSET sector but also within sub-sectors. This in turn requires more flexible quality assurance systems, both at

institutional and national levels, which are capable of assuring quality across a wider range of educational modalities with fewer common key indicators of quality. … agile education and training require accreditation to happen quickly" (DHET, 2020 (b): 40). The necessity to allow for flexibility and the need for institutions to be agile in their responses, unfettered by paralysingly bureaucratic processes of oversight and regulation cannot be overemphasised.

10. Conclusion

As a developing economy and a relatively young democracy with enormous socio-economic challenges, South Africa is still on a steep developmental trajectory. How it harnesses technology, especially those of the 4IR, to embrace new possibilities and promises for development, will make the difference between whether it leaps towards being a developed economy; plods along lethargically; or, at worst, stagnates or regresses. Addressing the numerous policy, regulatory, funding and planning challenges at national level is therefore crucial to the success of its developmental aspirations. Matters have not been helped by the Covid19 pandemic, whose negative effects on the economy, livelihoods and society are yet to be fully measured. What is clear though is that it would be shortsighted to fail to give the required attention to the potential and peril of the 4IR for our society and economy.

Acknowledgements

For advice, feedback, comments, or shared resources during the study, I am grateful to the following: Shireen Motala, Ahmed Essop, Thea de Wet, Emnet Woldegiorgis, Jeanette Botha, Lis Lange, Yuraisha Chetty, Mohini Baijnath, Theo Andrew, Jean Baxen, Britta Zawada, Chrissie Boughey, Denyse Webbstock and Alwyn Louw. Any shortcomings or omissions are entirely my own responsibility.

Abbreviations and acronyms

4IR	Fourth Industrial Revolution
AI	Artificial intelligence
Dx	Digital transformation
HEI	Higher education institution
MOOC	Massive Open Online Course
MTT	Ministerial Task Team
NDP	National Development Plan
PC4IR	Presidential Commission on the Fourth Industrial Revolution
PSET	Post-school education and training
SAQA	South African Qualifications Authority

References

Ally M and Wark N (2020) *Sustainable Development and Education in the Fourth Industrial Revolution* (4IR). Commonwealth of Learning, Burnaby.

Armstrong B (2018) *Exposure of the South African Economy to Technological Disruption. A sectoral view*. 4IRSA Report. Available at: https://www.4irsa.org/wp-content/uploads/2019/05/Exposure-of-the-South-African-Economy-to-Digital-Disruption-%E2%80%93-A-Sectoral-View-Working-Paper.pdf

Atherton G (2020) *University Access, Student Success and COVID-19 in a Global Context*. Research Brief. The Sutton Trust, London.

Badat MS (2020) The 4IR Super-Highway: A Dangerously Technocratic Utopia. *Daily Maverick.* 1 June 2020.

Barber M, Donnelly K and Rizvi S (2014) An Avalanche is Coming: Higher Education and the Revolution Ahead. *International Journal of Pedagogy, Innovation and New Technologies* 1 (1): 77-80. Available at http://doi.org/10.5604/23920092.1134803

Berry D (2020) The Ideal of a Digital-First University. *Stunlaw*. Available at: http://stunlaw.blogpost.com/2020/03/the idea of digital first university.html.

Chetty Y (2019) *SAQA and the NQF in the Context of the 4th Industrial Revolution: Realities and Implications*. SAQA, Pretoria.

Czerniewicz L, Mogliacci R, Walji S, Cliff A, Swinnerton B and Morris N (2021) Academics Teaching and Learning at the Nexus: Unbundling, Marketisation and Digitisation in Higher Education, in *Teaching in Higher Education: Critical Perspectives*. Rutledge, London. Available at: https://doi.org/10.1080/13562517.2021.1876019

Deloitte (2020) *The Fourth Industrial Revolution: At the intersection of readiness and responsibility*. Deloitte, London. Available at: https://view.deloitte.nl/Industry-40-Readiness-report-2020.html

DHET (2020) (a). *Students' Access to and Use of Learning Materials, Survey Report 2020* Department of Higher Education and Training, Pretoria. Available at: https://www.siyaphumelela.org.za/documents/600ff2719d9c1.pdf

DHET (2020) (b) *Report of a Ministerial Task Team on the Implications of the 4IR for the Post School Education and Training System*. DHET, Pretoria.

Du Preez J and Sinha S (2021) A Paradigm Shift in Higher Education in the Context of the Fourth Industrial Revolution. *IEEE Potentials*, March/April 2021: 1-5. Available at: file:///C:/Users/Client/AppData/Local/Temp/19131_Manuscript.pdf.pdf

Fataar A (2020) The Emergence of an Education Policy Dispositif in South Africa: An Analysis of Educational Discourses Associated with the Fourth Industrial Revolution. *Journal of Education*, no. 80: 5-24. Available at: https://dx.doi.org/10.17159/2520-9868/i80a01

Fraunhofer IPT (2018) *Industry 4.0 – Networked, Adaptive Production*. Institute for Production Technology (IPT): Aachen. Available at: https://www.ipt.fraunhofer.de/en/trends/industrie40.html

Fry J and Tinson P (2019) *Digital Leadership in HE: improving student experience and optimising service delivery*. Joint Information Systems Committee (JISC), Bristol, and Universities and Colleges

Information Systems Association (UCISA), Oxford. Available at: https://repository.jisc.ac.uk/7300/1/digital-leadership-in-he-jisc-ucisa-report.pdf

Gastrow M (2018) 'Policy options framework for the Fourth Industrial Revolution in South Africa'. SA–EU Strategic Partnership Dialogue Conference on Disruptive Technologies and Public Policy in the Age of the Fourth Industrial Revolution (10–12 December 2018). HSRC, Pretoria.

Gillwald A (2019) *SA must be wary of big promises made about 4IR*. Tech Central. Available at: https://techcentral.co.za/sa-must-be-wary-of-big-promises-made-about-4ir/93052/

Gleason N W (ed) (2018) *Higher Education in the Era of the Fourth Industrial Revolution*. Palgrave Macmillan, Singapore. Available at: https://doi.org/10.1007/978-981-13-0194-0

Jensen T (2019) *Higher Education in the Digital Era: The Current State of Transformation Around the World*. International Association of Universities: Paris. Available at: https://iau-aiu.net/IMG/pdf/technology_report_2019.pdf

Jivan A (2020) HR's Place in the Fourth Industrial Revolution. Fact Sheet Number 2020/01. SA Board for People Practices (SABPP): Roodepoort.

Jørgensen T (2019) Digital Skills: Where Universities Matter. *Learning and Teaching Paper #7* European University Association: Brussels.

Marwala T (2020) (a) *Closing the Gap: The Fourth Industrial Revolution in Africa*. Macmillan, Johannesburg.

Marwala T (2020) (b) 'Covid-19 has Forced us into the Fast Lane of the 4IR Super-Highway'. Daily Maverick. 28 May 2020. Available at: https://www.dailymaverick.co.za/opinionista/2020-05-28-covid-19-has-forced-us-into-the-fast-lane-of-the-4ir-super-highway/

Maton K (2014) *Knowledge and Knowers: Towards a Realist Sociology of Education*. Routledge, London.

Menon K and Castrillon G (2019) Reimagining Curricula for the Fourth Industrial Revolution. *The Independent Journal of Teaching and Learning*, 14 (2): 2-16.

Mishra S and Panda S (eds) (2020) *Technology-Enabled Learning: Policy, Pedagogy and Practice*. Commonwealth of Learning, Burnaby.

National Planning Commission (2011) *National Development Plan 2030: Our future - make it work.* The Presidency. Pretoria. Available at: https://www.gov.za/sites/default/files/gcis_document/201409/ndp-2030-our-future-make-it-workr.pdf

OECD/EU (2019), Supporting Entrepreneurship and Innovation in Higher Education in Italy, OECD Skills Studies, OECD Publishing, Paris, https://doi.org/10.1787/43e88f48-en.

PC4IR (2020) Summary Report and Recommendations: Presidential Commission on the Fourth Industrial Revolution. Republic of South Africa, Government Gazette No 43834, 23 October 2020. Pretoria: South Africa.

Peters M A (2019) 'In Age of AI, Universities will Need to Rethink their Purpose'. University World News, 18 January 2019. Available at: https://www.universityworldnews.com/post.php?story=20190116094437946

Reinitz B (2020) Consider the Three Ds When Talking about Digital Transformation. *Educause Review*, 1 June 2020. Available at: https://er.educause.edu/blogs/2020/6/consider-the-three-ds-when-talking-about-digital-transformation

Schwab K (2105) The Fourth Industrial Revolution: What It Means and How to Respond. *Foreign Affairs*, 12 December 2015. Available at: https://www.foreignaffairs.com/articles/2015-12-12/fourth-industrial-revolution

Tømte CE, Fossland T, Aamodt PO, and Degn L (2019) Digitalisation in Higher Education: Mapping Institutional Approaches for Teaching and Learning. *Quality in Higher Education* 25 (1): 98-114.

Williamson B and Hogan A (2021) Pandemic Privatisation in Higher Education: EdTech & University Reform. *Education International, February 2021*. Brussels: Belgium.

Vally S and Motala E (eds) (2014) *Education, Economy and Society*. Unisa Press, Pretoria.

Vettori O and Gover O (2020) Curriculum Design: Thematic peer Group report. *Learning and Teaching Paper #8.* European University Association: Brussels.

Xing B and Marwala T (2017) Implications of the Fourth Industrial Revolution for Higher Education. *The Thinker,* vol. 73, third quarter. Available at SSRN: https://ssrn.com/abstract=3225331

Zeleza P T and Okanda PM (2021) 'Promoting Digital Transformation with a 12-Point Agenda'. University World News. 11 February 2021. Available at: https://www.universityworldnews.com/post.php?story=20210208135348558